Near-inertial waves interacting with a coherent anticyclone off Peru

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Motivation

The interaction between near-inertial wave propagation and geostrophic flow was already investigated by Kunze (1985). Anticyclones can trap and enhance downward propagation of near-inertial wave energy. A critical-layer can be formed below these eddies where the associated vorticity anomaly vanishes. Several recent model studies point out the importance of this eddy near-inertial wave interaction for the downward transport of near-inertial energy into the deeper ocean. There it could provide an energy source for small scale dissipation. However, observations of critical layer trapping are rare.

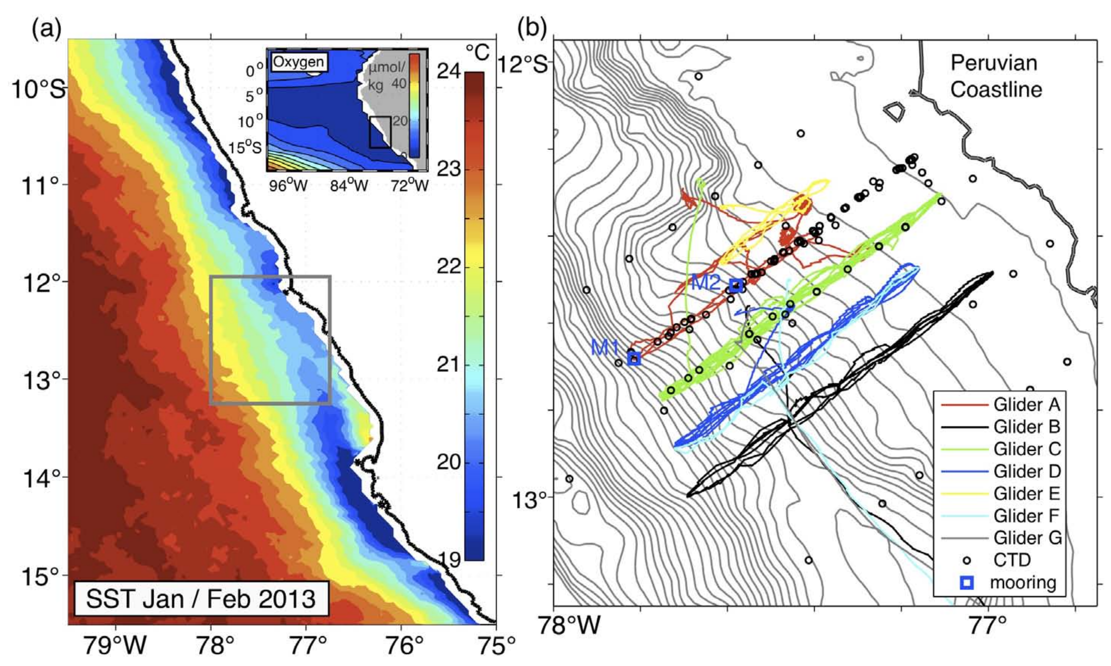

Figure 1: Mean sea surface temperature in Jan/Feb 2013 off Peru from MODIS in color (left). On the right: water depth (grey contours, 200 m interval), glider tracks (colored lines), CTD stations (black circles) and the two mooring positions (blue squares).

Experiment

A multi-platform observational study based on several gliders, moorings and shipboard measurements was carried out off Peru in January / February 2013 to investigate the interaction between mesoscale eddies and near-inertial waves.

Eddy formation

A coherent anticyclone formed in the study area allowing detailed investigation of its impact on the near-inertial energy distribution.

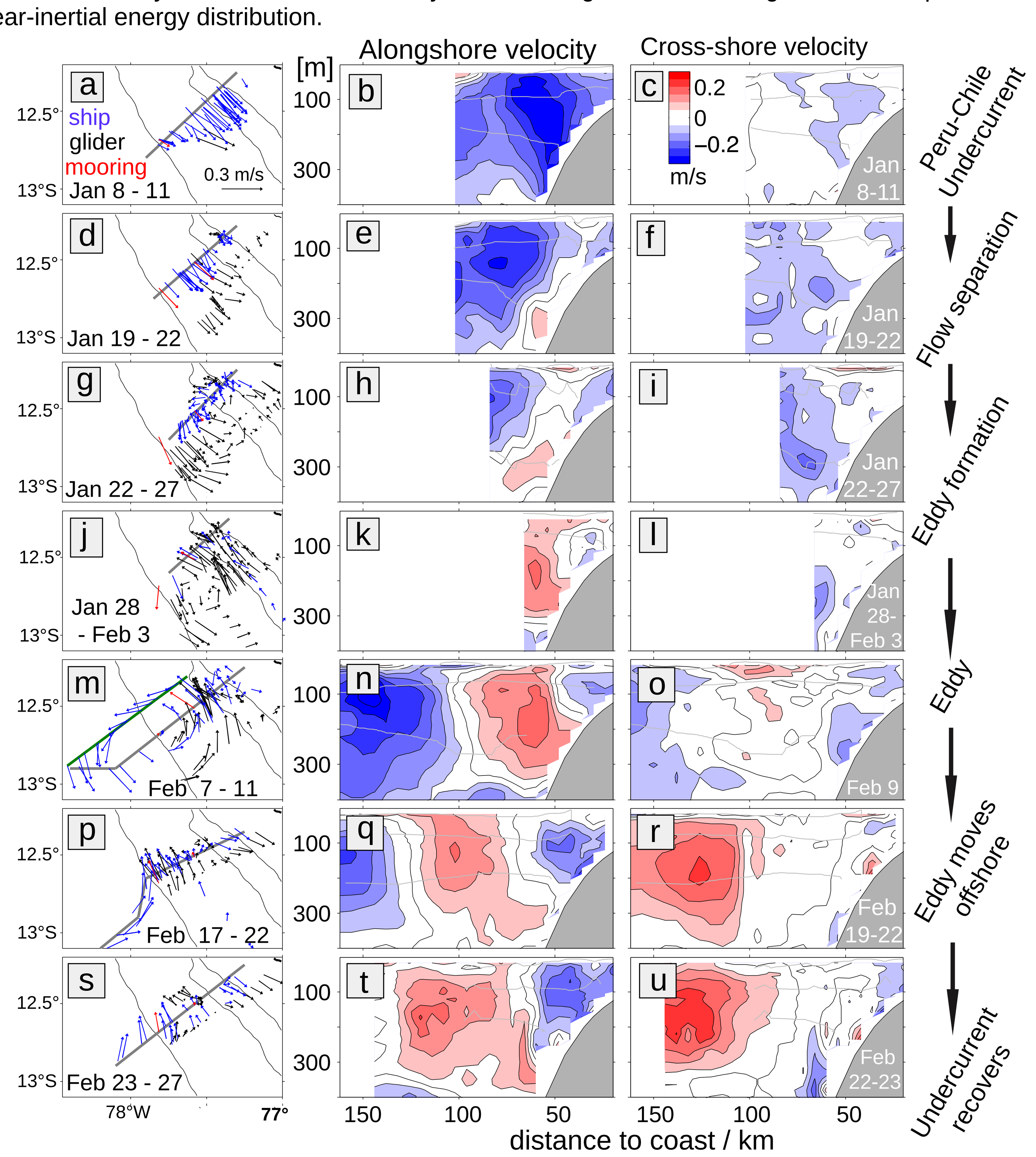

Figure 2: Left column: depth-averaged horizontal circulation for eight periods based on vmADCP (blue), moored ADCP (red) and glider drift-inferred velocities (black). The middle and right column show the temporal evolution of the along- and cross-shore velocity components (vmADCP) respectively along the grey transects (left column). Isopycnals (25.6, 26.2 and 26.4) in grey.

Eddy generation mechanism

Marshall and Tansley [2001] propose that the separation of a barotropic boundary current at a vertical sidewall takes place when r < L = (U/β)^1/2. Using a modified condition for flow separation of a boundary current accounting for topographic beta, it is shown that the conditions for flow separation is indeed fulfilled.

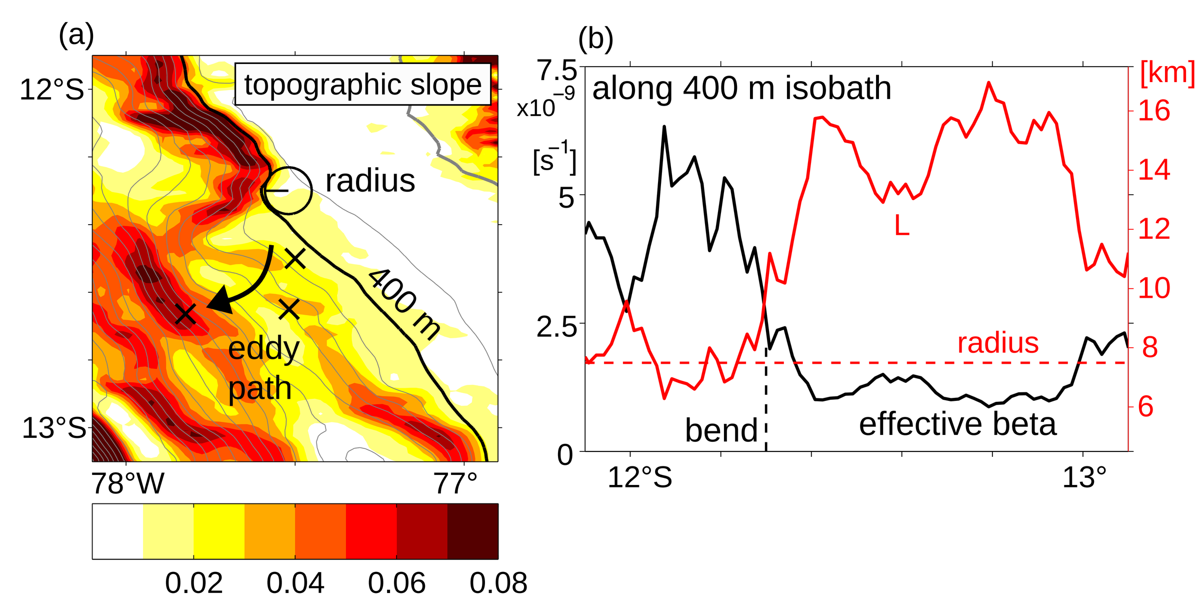

Figure 3: Left: bottom slope in color and depth (grey). The radius of the topographic curvature and the 400 m isobath are shown in black. The three black crosses indicate the position of the eddy centre at three different time periods (Jan. 22 - 27, Jan. 28 - Feb. 3 and Feb. 7 - 11). The right panel shows the effective beta (β eff) (black) and the resulting length scale L =(U/β_eff)^1/2 (red) along the 400 m isobath.

Near-inertial waves

Enhanced near-inertial energy (NIE) is found at the eddy base possiibly due to downward propagation of NIE within the anticyclone and NIW accumulation at a critical layer below.

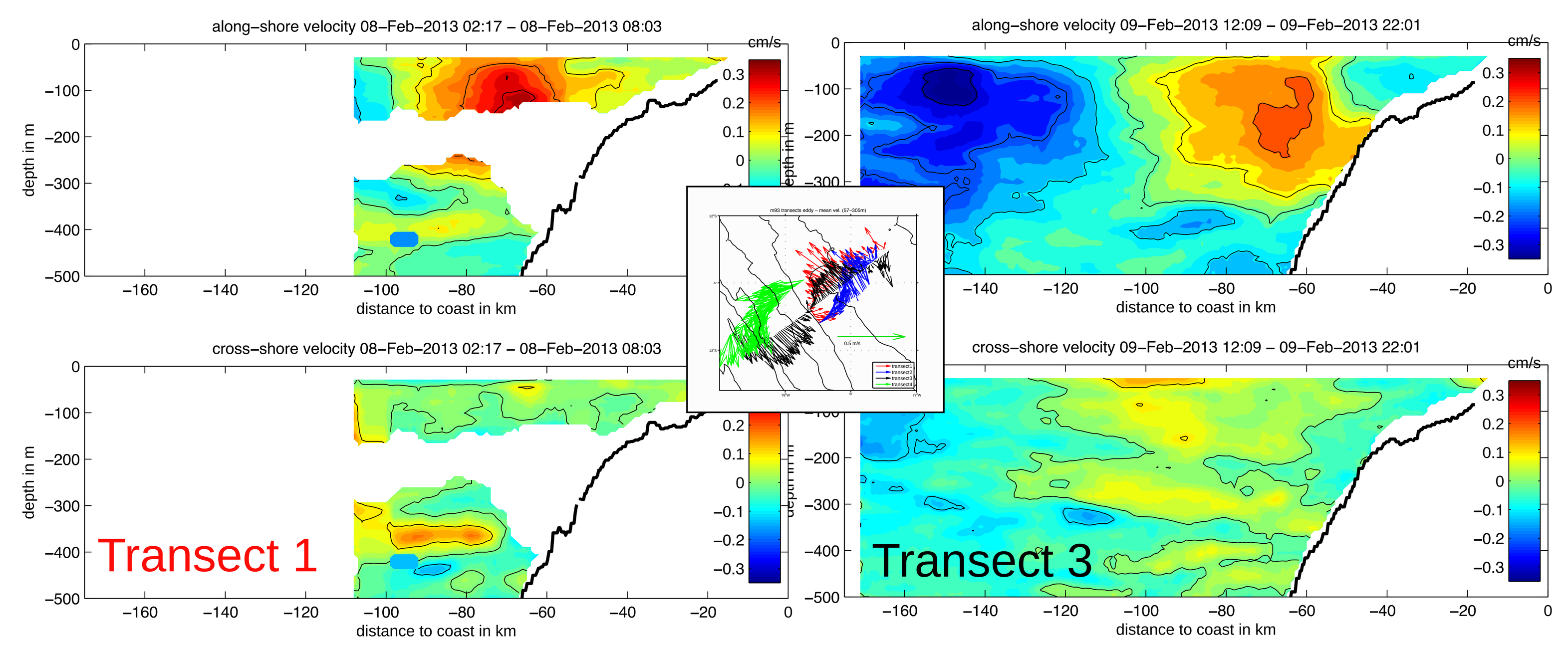

Figure 4: Along-shore velocity (upper panel) and cross-shore velocities (lower panel) through the eddy observed by vessel mounted ADCPs. Te middle panel show the position of the transects and the depth averaged near-surface velocity.

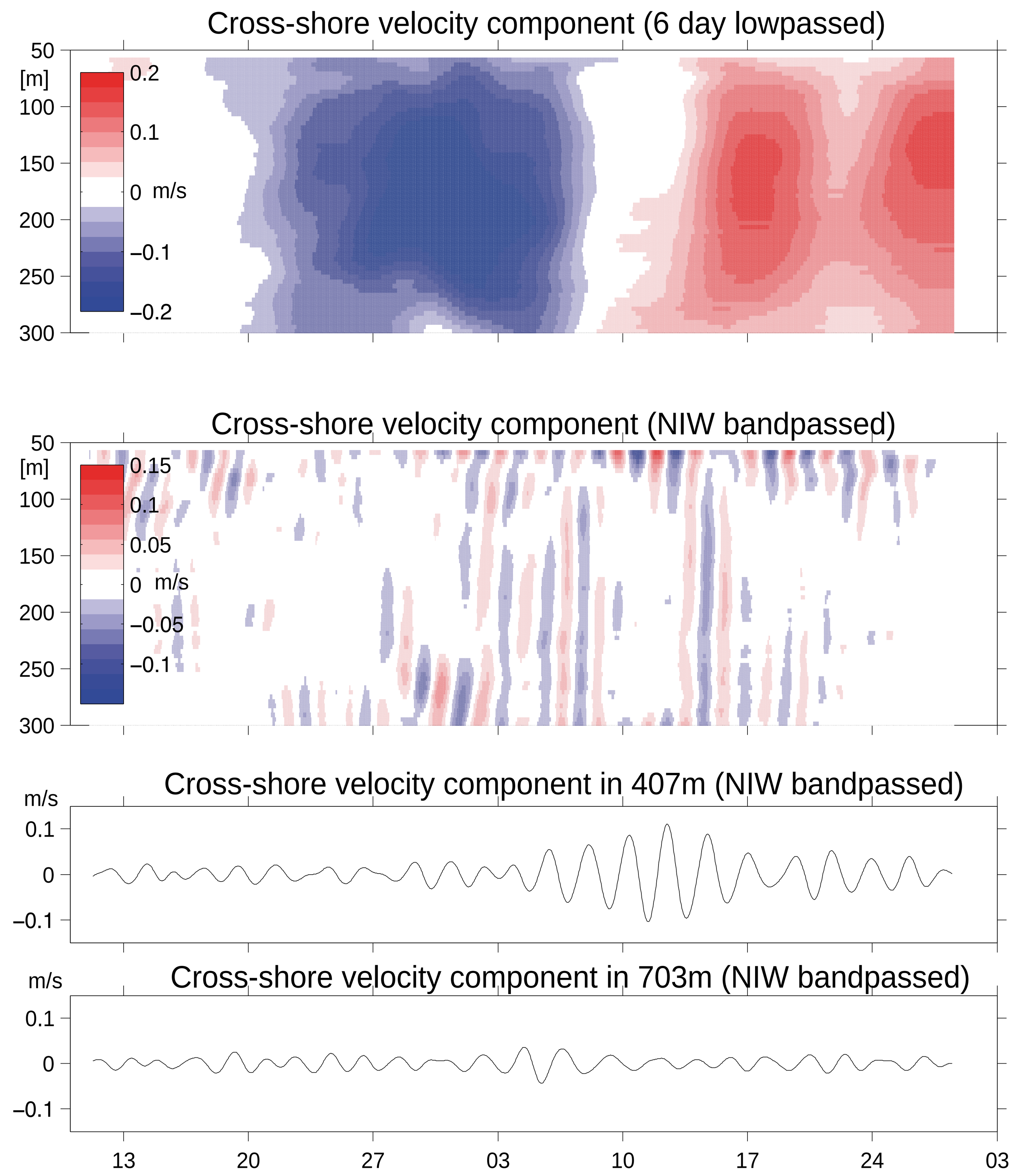

Figure 5 - Cross-shore velocity component from moored ADCP measurements between 50 - 300m (a) low passed (6 days), (b) NIW bandpassed (1.5-3 days) and RCM measurements at (c) 407 m and (d) 703m both NIW bandpassed.

Discussion

What are the sinks of NIE at the critical depth ? Kunze et al. (1995) suggest three possible pathways: into (1) mean flow, (2) untrapped waves or (3) dissipation

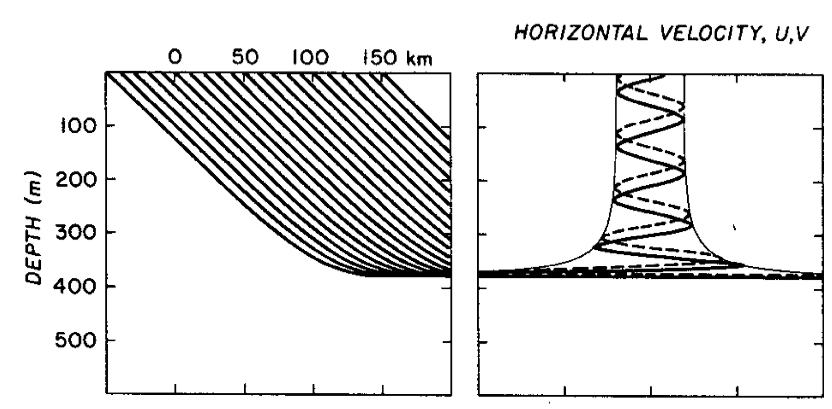

FIG. 14. Ray paths (left panel) and the numerical solution of (18) (right panel) for a vertically-varying effective Coriolis frequency. In the right panel the thick solid curve is the east velocity component u and the dashed curve the north component v. Waves stall at the critical depth where the effective Coriolis frequency is equal to their intrinsic frequency. Consistent with conservation of action-flux, the amplitude envelope of the wave behaves as $1\sqrt{Cg_z}$ (thin solid line).

Kunze 1985

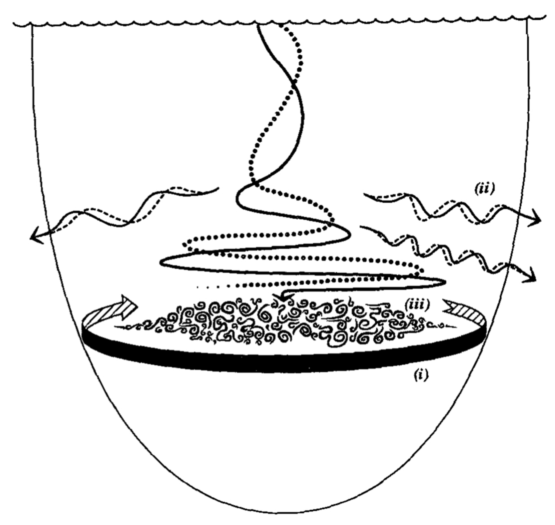

FIG. 1. Schematic illustrating the three hypothesized sinks for trapped near-inertial wave energy at a critical layer. A downgoing near-inertial wave has east (solid profile) and north (dotted profile) velocities 90° out of phase, so the horizontal velocity vector turns clockwise with depth. As the wave nears its critical depth, its vertical wavelength and group velocity shrink. Its energy builds up until it is lost to either (i) the mean flow, (ii) untrapped waves, or (iii) turbulence.

Kunze et al 1995

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Eric Kunze, 1985: Near-Inertial Wave Propagation In Geostrophic Shear. J. Phys. Oceanogr., 15, 544–565.
Eric Kunze, Raymond W. Schmitt, and John M. Toole, 1995: The Energy Balance in a Warm-Core Ring's Near-Inertial Critical Layer. J. Phys. Oceanogr., 25, 942–957.
Marshall, D. P., and C. E. Tansley (2001), An implicit formula for boundary current separation, Journal of Physical Oceanography, 31(6), 1633–1638, doi:10.1175/1520- 0485(2001)031¡1633:AIFFBC¿2.0.CO;2.